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Engineering With Nature Program

Arid Southwest Natural and Nature-Based Feature Workshop Summary

Held in Albuquerque District, May 7-8, 2025

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DRAFT 2025



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USACE facilitated workshop activities focused on project processes and Natural Infrastructure implementation. Photo credit Justin Graff, PAO, Albuquerque District.

Arid Southwest Natural and Nature- Based Features Workshop

Held in Albuquerque District, May 7-8, 2025

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Abstract

Communities in the arid southwest region of the United States are experiencing increased aridification, drought, and extreme precipitation events, causing property damage, putting lives at risk, and disrupting local economies. The Natural Infrastructure approach features measures and techniques that utilize ecosystem processes to reduce flood risk and improve resilience and water security in arid environments. However, current understanding of Natural Infrastructure measures is mostly limited to the ocean coast, resulting in lack of confidence on the applicability, costs, and benefits of these measures in the US arid southwest. This Technical Report summarizes findings from an Arid Natural and Nature-Based Features workshop held in Albuquerque, NM, May 7-8, 2025. Practitioners discussed challenges and opportunities associated with the implementation of Natural and Nature-Based Features. The workshop focused on three project processes: project purposes and authorities, design and implementation, and monitoring and measures of success and documented strategies and barriers for each process. Design resources and case studies are identified as examples of Natural and Nature-Based feature implementation throughout the arid southwestern United States. The result is a review of the current state of the practice and recommendations.

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Preface

This technical report was conducted for the U.S. Army Engineer Research and Development Center (ERDC) Engineering With Nature[®] (EWN[®]) research program under the project SON#2154: “NNBF Tools for the Arid Southwest.” The Program Managers were Dr. Jeff King, ERDC Environmental Laboratory and Dr. Amanda Tritinger, ERDC Coastal and Hydraulics Laboratory.

The work was led by the Ecological Resources Branch (CEERD-EEE) of the Ecosystem Evaluation & Engineering Division (CEERD-EE), U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Mr. Joseph B. Minter was Chief, CEERD-EEE; Mr. Mark D. Farr was Chief, CEERD-EE; and Dr. Jen Seiter-Moser, CEERD-EZT, was the Technical Director for EMRRP. The Deputy Director of ERDC-CERL was Dr. Brandon J. Lafferty and the Director was Dr. Edmond J. Russo.

LTC Josh Haynes was commander of ERDC, and Dr. Elizabeth C. Fleming was the director.

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1 Introduction

1.1 Background

Some areas of the US, particularly in the arid southwest, are experiencing increased aridification, drought, and extreme precipitation events. Flooding, both from extreme precipitation events and rain over burn scars, in recent years has caused property damage, put lives at risk, and disrupted local economies. The arid southwest has been subject to these dramatic changes for quite some time. Therefore, several nature-based measures have been developed to address these risks while providing a wide range of ecosystem and social benefits. Natural infrastructure approaches incorporate ecosystem function in infrastructure design and nature-based features aim to restore streams and landscapes using structures that mimic or foster natural processes. NNBF practices for the arid southwest exist but are not easily accessible to the engineering community.

Natural and Nature Based Features (NNBF) are measures and techniques that can be incorporated into infrastructure projects to reduce flood risk and improve resilience and water security. These are often made of natural materials and restore ecosystem processes that would otherwise be disrupted by conventional, concrete or hardened features. Currently, much of the advancements for incorporating NNBF in infrastructure occurs on the ocean coast (Figure 1, also Dolatowski et al., 2024). These measures have obvious incongruencies with arid environments, contributing to lack of confidence on the applicability and cost-benefit of these measures in the arid southwest.



Figure 1. Map of the United States EWN Implementation Toolbox, accessed 7/31/2021. Note the lack of NNBF examples in the arid southwest. (<https://ewn.erdcdren.mil/ewn-compass/>)

While working with communities, USACE Albuquerque District has identified a need for NNBF guidance specific to arid environments. Issues with intermittent flooding and erosion are well-known in engineering in arid environments. NNBF offers opportunities to mitigate risk by restoring ecosystem functions. Specifications were identified as a means to communicate these opportunities to permit applicants. Without greater understanding and guidance, the incorporation of NNBF in flood risk management (FRM) practices will not occur. Conversely, while there are individuals in organizations like USACE promoting the use of NNBF because of its opportunities in cost savings, addressing systemic issues, and other benefits, there are challenges in incorporating these features in existing conventional engineering planning frameworks. USACE also needs this guidance to confidently consider these types of measures.

Despite USACE's own limitations, NNBF is currently practiced in arid environments by many organizations. To gather information on NNBF practices, a workshop was held on May 7-8, 2025 at the USACE Albuquerque District, attended by 35 people. The key objective of the workshop was to identify the current state of the practice and identify means to more readily integrate Engineering With Nature® (EWN) concepts into

existing USACE project processes. Other desired outcomes of the workshop included identification of key barriers and challenges affecting the use of NNBF in arid environments to support further development of guidance and protocols to be provided to practitioners. The workshop is part of a project with the overall objective to develop a specific guide (“playbook”) for NNBF and multiple-lines-of-defense strategies to support future efforts to improve resilience in the arid southwest. The guide will identify NNBF that are appropriate to the arid region of the southwest US, substantially advance understanding of their potential performance, and improve confidence of federal, state, and local agencies to plan, design, and implement sustainable, adaptable, and cost-effective NNBF measures.

USACE hosted a two-day workshop inviting practitioners to present their design materials, discuss the breadth of NNBF applications in arid environments, identify benefits of NNBF, and discuss key challenges. Assessing the state of the practice informs current gaps and future research objectives.

1.2 Objectives

The objective of this Technical Report is to summarize the Arid Nature and Natural Based Features workshop. The stated objectives of the workshop were:

- Provide an opportunity for subject matter experts to share their ideas for designing and constructing projects in arid regions incorporating NNBF for maximizing flood risk management, as well as increasing economic, environmental, and social benefits.
- Work with partners to identify existing NNBF projects designed and constructed under a range of conditions in the arid southwest.
- Identify barriers (real or perceived, organizational or individual) to wider adoption of NNBF. This includes both during the planning and design phase of a project. Discuss areas of concern that have emerged following the use of NNBF in projects.

- Building on the above objectives, determine next steps including follow-on opportunities for collaboration to develop content for an NNBF Playbook for the arid southwest.

1.3 Approach

USACE identifies and addresses systemic challenges in technology and project processes through the internal submission of “Statements of Need” (SON) that are subsequently rated nationally for prioritization and research funding. This project and workshop were initiated from Statement of Need ID #2154, “Natural and Nature-based features (NNBF) Playbook for the Arid Southwest”. The Statement of Need posits that USACE Planning and Regulatory Divisions need NNBF resources for arid stream ecosystems. Issues cited are extreme weather events, drought, urban development, and wildfire which have significantly altered hydrographs and sediment transport throughout the United States and are particularly challenging in arid environments. In these regions, streamflow is often ephemeral; geomorphic form is dictated by channel beds and banks composed of alluvium and non-vegetated; and ecosystem function depends on sediment transport during intense flow events. Traditional hard structure treatments have been found to contribute to channel incision and disconnects streams longitudinally and from the floodplain. Closed, hardened structures may ultimately be unsustainable in the long-term due to sedimentation. While NNBF options may be better suited to realize desired outcomes for flood and erosion control, as well as supporting ecosystem services and water conveyance, current NNBF resources are limited or not well publicized for engineering communities.

The SON seeks a NNBF “Playbook” for practitioners to consider when developing restoration, flood risk management, and mitigation projects in arid environments. It is anticipated that though this playbook would be focused on the arid southwest, process and products from this study could be adapted to other regions facing extreme weather events, drought, urban development, and wildfire.

The intersection of USACE authorities with NNBF benefits are clear, including Flood Risk Management, Ecosystem Restoration, Cultural Preservation and Emergency Management. The USACE Albuquerque District has seen a practical need to work with NNBF, especially post-wildfire, in areas where access is limited. Remote areas, poor roads, difficult terrain contributes to limited access, which in-turn restricts the import of foreign materials and the use of heavy equipment (Haring et al, 2021). The need for this innovation in technology is analogous to when USACE received authority for restoration in the 1996 Water Resources Development Act Section 206- which demanded a shift in design culture. Practical opportunities include alignment with customer values and reducing cost. USACE work is partner-driven, and the work often requires cost-share. Local sponsors live with the impacts of construction, have a financial stake in the project, and are often responsible for long-term monitoring and coordination of maintenance. NNBF features may increase the appeal of project alternatives and increase flexibility for the project in the long-term.

2 Data Collection Methods

Invitees were identified via key informants in the USACE Albuquerque District, including a contact list developed by the SON originator. Additionally, the workshop was introduced at the NM Wetlands Roundtable after a presentation about linking ecological models and hydraulics modeling (Harris and Cushway, TBP). The invitees were invited to forward the workshop invitation to others. There were 39 attendees from 18 different organizations, including international, federal, tribal, state and local governments and non-governmental organizations (Table 1).

Table 1. Organizations that attended the workshop.

Organization Type	Organizations Attending
International Government	International Boundary and Water Commission
Federal Government	US Bureau of Reclamation, US Department of Agriculture
Tribal Government	Santa Ana Pueblo, Santa Clara Pueblo
State Government	NM Energy Minerals and Natural Resources Department, NM Department of Game and Fish, NM Environment Department
Local Government	Bernalillo County, Southern Sandoval County Arroyo Flood Control Authority
Non-Government	Amigos Bravos, Audubon, National Forest Foundation, Rio Grande Return, Hermit's Peak Watershed, American Rivers, The Nature Conservancy, Bohannon Huston

The workshop was organized around project process themes: project scoping, implementation, and monitoring. Talks were

Theme 1, Purpose and Authorities: For what purposes are NNBF used? Discuss how an agency or organization's programs support implementation of NNBF, how the purpose of an NNBF informs design criteria, materials used, or implementation

workshop polls featured structured questions around each theme: 1. How significant are the challenges associated with this theme? (0 being “Not Difficult”, 10 being “Extremely Difficult”) and 2. In a word, name these challenges. Major themes were coded from the raw survey entries, which are listed in Appendix B. A post workshop survey solicited unstructured comments, which were organized along with workshop notes to develop this report (See Appendix E for raw results). Agenda featured a worksheet to submit existing design resources and case studies (See Appendix D for the template worksheet). An opening icebreaker recorded across the themes produced a brainstorm list of challenges associated with each theme as well as recording case-studies on a spectrum of natural to conventional infrastructure. Also, break-out groups were held throughout the workshop with semi-structured questions regarding opportunities and existing resources, and informing a specification-like framework based on a strawman developed by USACE practitioners (See Appendix C for the draft framework used in the exercise). In addition to the three themes, workshop participants were also encouraged to consider:

- The connections between social, ecological, and technological systems and the impact, both intended and unintended, of human response to the environmental challenges produced by extreme weather events in the arid southwest.
- How USACE processes and organizational culture might inhibit use of NNBf when and where they might sensibly be applied.

The findings are collated and organized here.

3 Purposes and Project Authorities Theme

Purposes and Authorities was designated as a theme because the project purpose affects criteria for selecting NNBF, how NNBF would be designed and implemented, and how their success is evaluated. Workshop attendees identified project purposes related to sediment management, water management, habitat creation and social use (Figure 2).

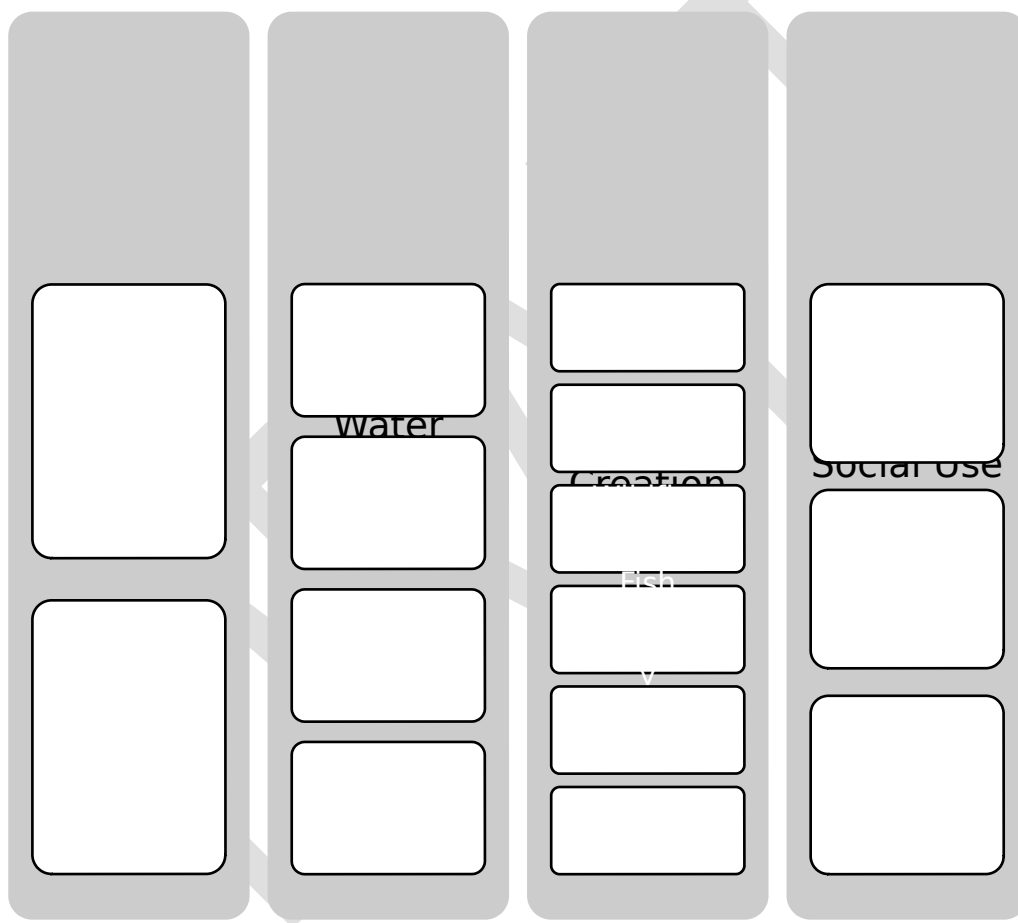


Figure 2. NNBF project purposes identified in the Arid NNBF Workshop, organized into four major themes.

USACE activities are authority-based, that is, every activity USACE undertakes must be authorized under law. In considering what authorities may have interest in arid southwest NNBF, the workshop attendees identified the

following legislation, programs, or social purposes that align with the benefits of NNBF:

- Property owners and water owners may desire NNBF solutions because increased ecosystem function aligns with their values, increases water retention, and reduces material risks.
- Local ordinances may require green or hybrid approaches for stormwater management.
- Wild and Scenic Rivers require their unique, natural qualities to be protected and enhanced, and NNBF would be aligned with this goal.
- Several national pieces of US legislation, including the Clean Water Act, Endangered Species Act, National Environmental Policy Act, Water Quality Act each seek to reduce negative impacts to the environment and natural resources, a purpose that is furthered by NNBF.
- More generally, NNBF may have footholds in decision-making processes that value other social effects, seek multi-purpose or multi-benefit outcomes, and other permitting requirements.
- NNBF may be relevant in projects with concerns for water quality affecting municipal water supply.

Regional and landscape planning such as State action plans are appropriate for NNBF implementation. Systems planning is more effective than disparate efforts. Given the scale of issues associated with restoring ecosystem function, stakeholders may be affected by project activities or manage lands around or downstream of these areas. Navigating potential multiple-use conflicts such as water rights, grazing, recreation, and wildlife habitat, is expected. Project activities may provide benefits such as increased resiliency, and may affect water, sediment, and energy regimes. NNBF may be appropriate to help reduce fire risk in high-risk areas, and adjacent ecosystem functions support threatened and endangered species initiatives. It is important to identify project areas where upland vegetation

treatments (such as timber and fuels reduction) are occurring to treat the watershed holistically.

4 Implementation and Design Theme

An aspect of nature-based feature projects is the importance of implementing the right project in the right place. This requires systems-thinking and will require collaboration across a multidisciplinary team and local stakeholders. It is warranted to consider local and traditional ecological knowledge for site context. A unique aspect of nature-based features design is to assess whether natural processes are enhanced. For example, how the structures improve connection to the floodplain and where channel movement is expected in response to structural implementation. Features may also support sediment continuity, which is otherwise restricted in hardened structures. Typically, nature-based features in these systems are placed high in the watershed, attenuating flood peaks downstream and increasing groundwater storage. Given arid environment conditions, rainfall timing is uncertain. This uncertainty as it relates to revegetation cannot be taken for granted.

One of the workshop ice-breaker activities was to place existing structure-types on the spectrum of most natural to most artificial. A figure from Van Rees et al (2023) was used as a template to represent for this spectrum. Workshop attendees placed sticky-notes on this figure. Other structures mentioned during the workshop were added in post-processing. 59 types of structures were identified (see Figure 3).

Specific case studies were recorded and presented in the following paragraphs. Findings indicate that “Hybrid” features, falling somewhere between natural and artificial, were the most common. Similarly, the centroid of existing case studies was slightly more artificial than the middle of the spectrum. Here are specific case studies ordered from most natural to most artificial:

- Supporting existing beaver populations for fire resilience in Santa Clara Creek (Fairfax and Whittle, 2020)

- Trees, Water, People constructed Post-Assisted Log Structures (PALS) in the Mancos River to support the riparian corridor and ecosystem function.
- Process-based restoration including water retention structures, vegetation management, erosion management on trails in the Little Green Valley Fen, Tonto National Forest.
- Floodplain swales and PALS in the Hermit's Peak and Calf Canyon Fire burn area.
- Rainwater harvesting basin and soil sponges at Gutierrez Hubble House to increase water retention.
- San Juan River Basin Recovery Implementation Program includes fisheries management, fish passage, and strategic water release. (USFWS, accessed 2025)
- Copperas Creek the bank toe protection with stream barbs to reduce erosion. The area has developed extensive willows and beavers have moved in and are helping to stabilize the channel. (Rock Island County SWCD, 2018)
- Root wads for Tijeras Creek Watershed Restoration Project (Ciudad SWCD, accessed 2025)
- Log-check structures, wood mulching and toe protection in Santa Clara Creek to restore stream. Naturally occurring seeps were incorporated in the design.
- Saxon Creek Aquatic Organism Passage Project replaced a failing road culvert and bridge along with realigning and restoring the river channel. (NTCD, Accessed 2025)
- Stormwater rain gardens in urban areas filter water and reduce storm runoff.
- Interrupting connected impervious areas, such as the roof-to-driveway-to-road interface, to reduce storm runoff (Schoener, 2018).
- McEwen Storm Drainage Pond modified with native plantings to support habitat functions, effectively improving water quality of its outflow (Travis et al, 2023).
- Rio Grande Grade Control Structures to reduce channel incision in Santa Ana Pueblo

- NM Game and Fish implemented channel restoration including pool excavation, rock and wood in-stream structures, and wetland improvement. Fish stocking occurred after construction. (Moffatt, 2017)
- NMDOT US Hwy 180 Gila River Project: Project goals are infrastructure safety (protection of the US Hwy. 180 bridge) and habitat improvement using nature-based solutions by creating an off-channel wetland to help dissipate flood flows upstream of the bridge.

Parking Lot (I cannot find sources or more information about these projects):

- Santa Clara Culvert Post-Fire Emergency Project
- Little Green way
- NFFs LTPBR in CRB project portfolio
- Pueblo habitat restoration and MRGCD- Control

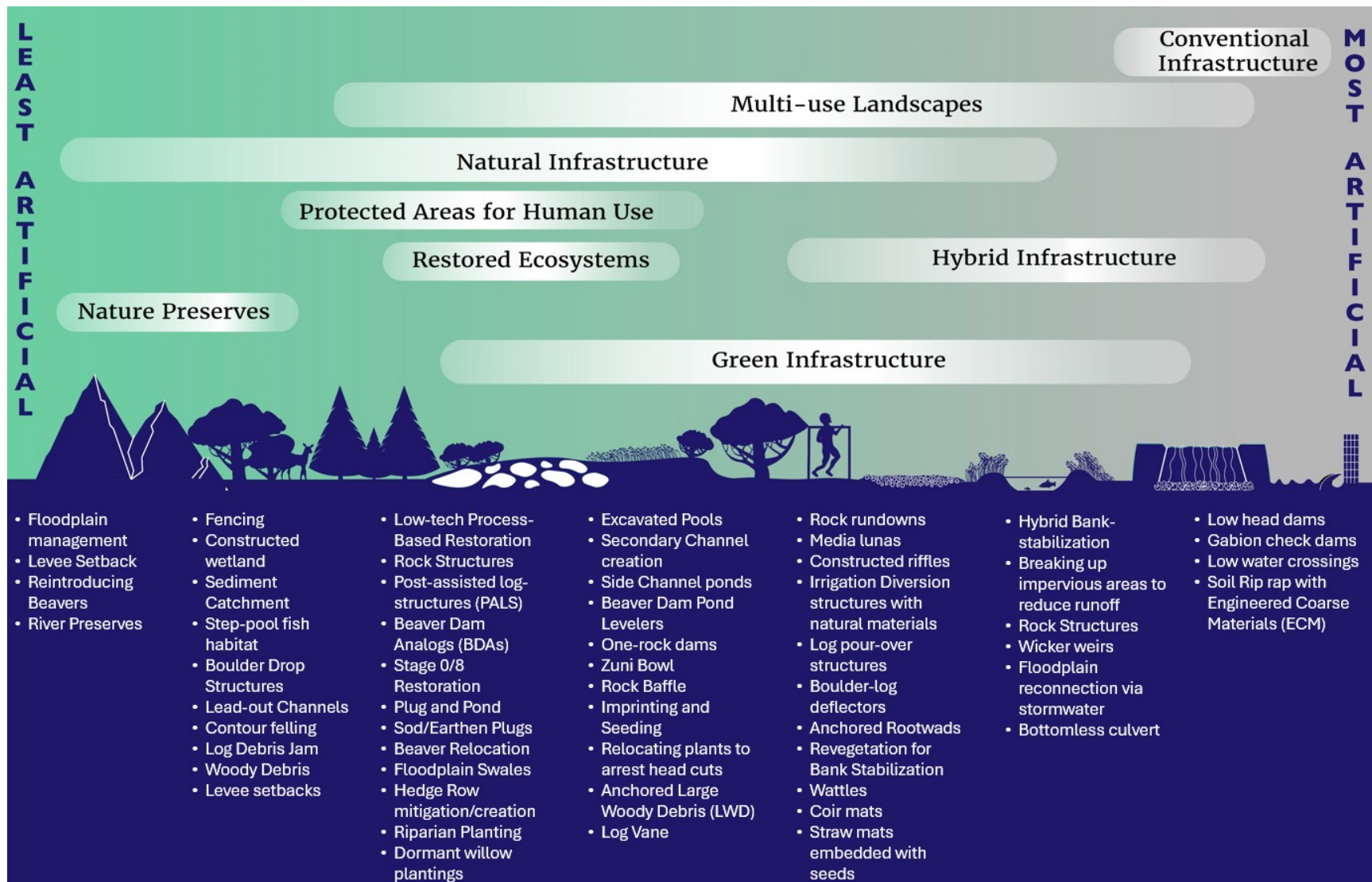


Figure 3. Modified from van Rees et al (2023), workshop results of structural options used in arid southwest environments, placed on a spectrum of least artificial to most artificial.

4.1 Arid NNBF Design Strategies

As mentioned previously, natural infrastructure design requires a systems-thinking approach. This effectively means that the “problem” that a project may be trying to address is likely a “symptom” of widespread trends occurring upstream and downstream of the issue, for example an eroding bank or a flood-prone area. As part of the design process, one should consider potential downstream impacts, appropriate placement upstream of the problem area, and a watershed-scale perspective. The implementation of a feature should be evaluated as part of a process and larger system. Design should not only consider structural integrity during the target flood event, but how the structure operates across the range of potential flows to reduce adverse outcomes (Furniss et al, 2003). For example, in conventional engineering, culvert design may assess the 10-year event, but sediment accumulates at the more frequent events, causing maintenance issues that could otherwise be avoided.

The use of NNBF calls for an in-situ approach, that is: using local materials, benefiting the local community and wildlife, and developing ecological services in a sustainable manner. The incorporation of perspectives from Indigenous people and other land-based communities within the project area is highly recommended. Local and Traditional Ecological Knowledge such as vegetation succession, historical land uses, and flow-landscape relationships can provide opportunities for project efficiencies or effective technologies given the site context.

The use of natural materials presents both an advantage and challenge. The availability of rocks, willows, and wood at the project location should be assessed. Materials generated from the construction (i.e., sediment, woody materials) may be used as additional features on the site. Not only does it reduce costs of removing these materials, but it may also increase desired functions of water retention and natural revegetation.

Conversely, use of natural materials presents some risks, as the structural integrity of these materials can be uncertain. To

redress potential failures of individual features, it is encouraged to develop a “features complex” instead of a single structure. The complex of features creates redundancy and increases site resilience. Planning for structural “failure”, such as feature succession with deformable features, can be incorporated in the design to reduce adverse outcomes. For example, allowing buffer areas for river adjustment after structural placement helps set expectations of site succession following a project.

An additional component of site succession is awareness of eventual maintenance activities. Incorporating a maintenance plan is recommended. Vegetation efforts should use native vegetation, as these species are most adapted to local precipitation patterns. After a large runoff event, it is recommended to visit the site to see if adaptive management is needed. The implementation of structural features is expected to affect flow paths, and additional material placement may be necessary over time. Therefore, avoid large structures and avoid crossing waterways. Features such as vegetation, beaver dam analogs, leaky dams, are likely to retain sediment and are best used in headwaters for long-term function. It is also recommended to avoid design features that would need to be removed later. When a project site allows for the river to adjust for intense events, less hardened structures are appropriate.

4.2 Design Analysis for NNBF

When it comes to design analysis, site context is key. During initial site visits: identify the flow patterns, sediment deposits, water surface (e.g., smooth and rapid flow areas). Assess what sediment types are found in the stream and what is on the floodplain. It is also key to visit the site at different times of the year. It is recommended to learn about the history of the project area, in order to assess changes of ecosystem function over time. Identify what natural process are occurring and how can NNBF's be integrated to work with them, not against them. The use of reference reaches helps delineate reasonable expectations for site outcomes.

Other site context considerations are the location in watershed, upstream areas draining into the project area, soil type and steepness of grade, land use, and any other constraints. Hydraulic analysis will be necessary to assess fluvial geomorphic trends, environmental flows and flood frequency, and sediment transport analysis for the scour potential.

Since many of these solutions are best applied in the headwaters of the watershed, it is important to consider the site accessibility for laborers, material, equipment. Importing foreign materials, use of heavy equipment including creating access roads, staging sites, may be contrary to project objectives because of adverse site impacts. One may consider reducing these impacts as part of the project plan, either by removing the process or mitigating negative impacts. One way to mitigate impacts is the use of “wet meadow mats”. Byproducts of the project construction, such as debris and salvage trees can be used on site to create features, for example Beaver-Dam-Analogs or Post-Assisted Log Structures.

4.3 Design Resources

Workshop attendees provided several existing design resources, listed here:

Allen, E. B. ND. Restoration Ecology: Limits and Possibilities in Arid and Semiarid Lands.

Bernalillo County. Green Stormwater Infrastructure and Low-Impact Design Standards and References. Featuring several urban design standards, plant lists, and related ordinances. <https://www.bernco.gov/public-works/public-works-services/water-wastewater-stormwater/stormwater/green-stormwater-infrastructure-and-low-impact-development/green-stormwater-infrastructure-and-low-impact-design-standards-and-references> (Accessed 7/25/2025.)

Biedenharn, D.S., Elliott, C.M. and Watson, C.C. 1997. The WES Stream Investigation and Streambank Stabilization Handbook

Briggs, M.K. and Osterkamp, W.R. 2021. Renewing Our Rivers: Stream Corridor Restoration in Dryland Regions. University of Arizona Press. 488 pp.

Fischer, R.A. 2003. Riparian restoration and management needs in the arid and semi-arid western United States. Technology News from the USACE Ecosystem Management and Restoration Research Program.

Haring, C., Murray, A., and Luna, F. 2023. Sustainable bank and channel stabilization techniques in arid southwest streams. ERDC/TN WRAP-23-3. <http://dx.doi.org/10.21079/11681/47380>

Haring, C. and Biedenharn, 2021. Channel assessment tools for rapid watershed assessment. Environmental Science. DOI:[10.21079/11681/40379](https://doi.org/10.21079/11681/40379)

Lancaster, B. 2019. Rainwater Harvesting for Drylands and Beyond. Revised Third Edition. Rainsource Press. 288 pp.

Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. Wheaton J.M., Bennett S.N., Bouwes, N., Maestas J.D. and Shahverdian S.M. (Editors). 2019. Utah State University Restoration Consortium. Logan, UT. 286 pp. DOI: [10.13140/RG.2.2.19590.63049/2](https://doi.org/10.13140/RG.2.2.19590.63049/2).

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

Stromberg, J.C., Lite, S.J., and Patten, D.T. 1999. Provo River Restoration Project: Riparian Vegetation. Prepared for Utah Reclamation Mitigation and Conservation Commission. Salt Lake City, UT.

Zeedyk, B. and Clothier, V. 2014. Let the Water Do the Work: Induced Meandering, an Evolving Method for Restoring Incised Channels. Chelsea Green Publishing, 254 pp.

Zeedyk, B. 2006. A Good Road Lies Easy on the Land... Water Harvesting from Low-Standard Rural Roads. Quivera Coalition, Zeedyk Ecological Consulting, LLC, The Rio Puerco Management Committee - Watershed Initiative, and the New Mexico Environment Department - Surface Water Quality Bureau..

Additionally, these organizations were identified as knowledge resources:

American Rivers Riverscape Restoration Network, Anabrach Solutions, Ecological Society of America (ESA), National Association of Wetland Managers (NAWM), Rio Grande Return, Society for Ecological Restoration (SER)

- [Parking Lot \(Not found\): Zeedyk: Riparian Enhancement thru road design; Watershed Arkansas; NRCS NEH Docs Tech supplements, Whisenhunt 1995, Avazfoor 2018, Roskins , BAER](#)

5 Monitoring, Maintenance, Adaptive Management, and Measures of Success Theme

Monitoring was identified as the most important tool to improve NNBF implementation, but also the most neglected in current practice. Monitoring should begin prior to site selection. Data should be collected to clearly delineate the baseline condition, and conditions should be continuously assessed during construction and post-construction. The monitoring objectives should be clearly defined, though objectives may vary depending on project partners, permitting, and funding requirements. Additionally, monitoring objectives may be informed by local conditions and by the experience of those constructing the features.

Monitoring enables a team to narrate project effectiveness over the long-term. Many NNBF treatment actions depend on the system doing the work, such as high flow events that “work” the constructed project and the system according to its components (wood, beaver mimicry, vegetation, etc.). Given the irregularity of rainfall events in arid regions, the project function of both NNBF and conventional engineering projects over high flow events is more telling than monitoring during the immediate years after project construction if those years have only baseline flow events.

Common feedback from stakeholders indicates that nature-based solutions require maintenance and adjustment as conditions evolve, but providing maintenance is challenging because these activities occur after project “completion” and no funding was set aside. Monitoring needs to be valued more than it is currently. For NNBF, adaptive management is needed to ensure the project continues to mesh with the site context as conditions evolve. Monitoring and adaptive management can inform future project design because practitioners may anticipate response in a similar project setting. It is also easier (less expensive) to implement small changes that can only be observed with regular assessment. Additionally, in many areas

where NNBF is applied, such as burn scars, the science is continuously improving. Therefore, monitoring, maintenance, and adaptive management needs to be included in the project cost and schedule.

5.1 Variables of Monitoring Interest

As stated previously, monitoring objectives vary according to permitting, funding sources, the context of the site, and stakeholder interests. In all cases, monitoring should have clearly defined objectives, and the monitoring procedure should capture information relevant to the objectives. Reflecting on original project goals and analyses will support defining monitoring objectives. Regarding permitting: monitoring durations are related to the period of performance and whether the project is considered a “stop-gap measure” or a more involved, large-scale effort. Permits may also indicate what shall be monitored. Site context, such as features, available materials (e.g., rock, native and exotic vegetation) and the longevity of resources and materials used in construction affect monitoring planning. Anticipating likely adjustments on the project site and adjacent areas can help steer monitoring extents.

5.1.1 Materials and Personnel

Typically, monitoring efforts include repeat visual inspections, which would occur prior to project development and continue after construction. Identifying funding, the responsible agency, seasonal timing/annual frequency, and reporting is a prerequisite. Standardizing the reporting method, including where and how data is stored helps with continuity, especially with the likelihood of staff turnover. Developing a Standard Operations Procedure including georeferenced field monitoring sites has been found to be helpful.

Versatile datasets that can be collected during field monitoring are georeferenced photographs, cross-section measurements, depth and velocity measured via flowmeter, and other geomorphic measurements such as substrate and vegetative cover. Sensors such as trail cameras or in-situ water quality monitoring probes can provide information in between site

visits. Drones can be used to identify large-scale changes to the site. USGS gages, LiDAR, and aerial imagery may be accessed as public datasets.

5.1.2 Geomorphic Factors

With NNBf, both the constructed structures and the surrounding channel are expected to adjust. The magnitude of change can be measured via geomorphic monitoring. After a channel-forming flood event (1- to 5-year event), the installed features should be inspected for their ability to self-sustain or need for intervening adaptive management. The permanence of the materials used are a factor in timing this evaluation.

The bank erosion hazard index (BEHI, Rosgen 1996) would be used both during pre-project siting and should be updated after feature implementation. If high flow channels are present, assess whether they're functioning. Channel width, bar and island formation, and other changes in sediment transport regimes should be documented.

5.1.3 Hydrologic Factors

Hydrology is a difficult factor to assess during a field visit, as every field visit will only be a snapshot in time. In-situ monitoring probes can provide information about water quality, temperature, and stage. Reductions in flood impacts, and evidence of water retention in the landscape or behind constructed features, are often linked to project objectives and therefore important to monitor. For broader trends, the same hydrologic and hydraulic analysis that was conducted for project planning can be conducted post-construction to evaluate project effectiveness.

5.1.4 Biologic Factors

Biological monitoring may include vegetation inventories, particularly capturing the structural mosaic, and assessing whether exotic or native species are being recruited. Additionally, species of management and conservation concern will likely be monitored according to project objectives. Soil

temperature and moisture are important to measure but can be expensive data to collect. Identification of proxies, such as water temperature, may assist in reducing overall monitoring costs.

5.2 Adaptive Management

Ultimately, monitoring enables teams to evaluate project effectiveness and provides an opportunity to either redress unforeseen issues or improve design efforts in the future. Elements that are important to consider include: communicating lessons learned to the public and other practitioners; documenting benefits to improve permitting processes; documenting cost/performance relationships; and assessing the scope of the construction footprint relative to the project impact footprint.

5.3 Monitoring Resources

Workshop attendees provided several local monitoring resources, listed here:

NM Environment Department. Wetlands Rapid Assessment Methods. <https://www.env.nm.gov/surface-water-quality/wetlands-rapid-assessment-methods/> <Accessed 07/28/2025>

NM Conservation Information System. Including NM Environmental Review Tool, Environmental Data, information about rare plants and arthropods, and multiple spatial databases. <https://nhnm.unm.edu/data> <Accessed 07/28/2025>

NM Riparian Habitat Map. <https://nhnm.unm.edu/riparian/NMRipMap> <Accessed 07/28/2025>

US FWS Tracking and Reporting Actions for the Conservation of Species System (TRACS). Contains required performance goals and accomplishment reporting, as well as lessons learned. Requires DOI log-in to access. <https://tracs.fws.gov/login>

6 Challenges

An important element of discussing the state of the practice was to highlight current barriers and challenges associated with implementing NNBF in arid environments. During the Q&A sessions after presentation modules of the first day (See Appendix 1 for workshop agenda), polls were conducted (Appendix 2), and notes were taken to record challenges. Additionally, the second day of the workshop had breakout sessions focused on articulating the challenges associated with the purposes, design, and monitoring project processes. Attendees were randomly assigned to breakout groups dedicated to each project process; there were (6) breakout groups – two dedicated to each project process. The challenges that were identified by these various means of data collection are recorded here.

6.1 Challenges associated with Arid Environments

A characteristic limitation in the arid environments is water availability. Rainfall timing is variable, making revegetation objectives difficult to achieve. When rain events do occur, hydrographs are typically flashy followed with long periods of no water. Areas of flowing water are often intermittent or ephemeral. The lack of water leads the public to be unaware of the power of the big, flashy events that occasionally occur. That being said, native vegetation and fauna are adapted to water scarce environments, and even scant water supplies can support ecosystem function.

Balancing social and biological needs for water is a source of tension in arid environments. For example, grassland restoration may use water, but water supplies are often overallocated under persistent drought conditions. While the water may be intersected upstream of water users', intercepted water will still be released at perhaps a smaller volume but more continuously. For watershed function to be restored, livestock would need to be excluded from areas year-round for 5 to 7 years. Loss of riparian areas have contributed to dismal

water quality outcomes: half of New Mexico's waters do not meet water quality standards, particularly temperature.

The highly modified rivers are experiencing incisions and erosion issues, as well as gully formation given the loss of vegetative cover. The erosion increases sediment loading in streams and propagates a variety of issues.

6.2 Challenges Associated with Project Processes

Some challenges with implementing NNBf are persistent challenges that affect traditional engineering as well. Erosion and sediment control are often issues around new structures. Downstream effects caused by changes in sediment regime may be unaccounted for. There is a lack of monitoring to inform adaptive management or future designs.

Other challenges are particular to NNBf. Many contractors are unfamiliar with NNBf approaches and therefore may be hesitant to try new techniques. There is a lack of guidance and specifications, especially to the level of detail that are available for hardened engineering techniques. Additionally, the lack of records regarding the costs to install NNBf and their benefits makes it difficult to effectively incorporate NNBf into alternatives analysis.

6.2.1 Purposes and Authorities Challenges

Project Processes related to purposes and authorities was rated as the least challenging project process, with a median score of "6" or somewhat challenging (See Appendix 2). Major terms related to purposes and authorities related to challenges had to do with navigating regulatory processes and permitting (Figure 4).

When it comes to existing authorities, it is difficult to identify which authorities are involved with prioritizing NNBf approaches. Agency guidance is sparse and in many cases top-down: a policy directive without supporting guidance sufficiently detailed to inform implementation.

When it comes to permitting, opportunities are limited despite opportunities for NNBF to mitigate long-term adverse effects. USACE doesn't have authority to tell an applicant how to do a permit, and the scope of reviews is limited to see if the proposed action meets the intent of the permit. Waters of the US concerns are focused on areas with perennial flow, which is an atypical flow regime in arid regions. Nationwide permits strive for minimal effects to the existing condition. Instead, NNBF focuses on restoring processes that are degraded in the existing condition. The benefits of NNBF take several years to be realized, which does not correspond to current contracting nor permitting structures.



Figure 4. Word cloud from the Purposes and Authorities Poll (n=21).

Nature-based solutions have larger project visions than conventional engineering approaches. NNBF approaches consider systematic issues, such as a watershed perspective. The expansion of these scopes of interests broadens the partner and stakeholder community, requiring higher levels of coordination. Generally, increased stakeholder engagement has a propensity to increase risk aversion, which may be limiting

considering NNBF techniques are less widely utilized and not well known. Therefore, educating the greater community and stakeholders about NNBF is often imperative. Projects that affect water conveyance come across water capture limitations (e.g., the 96-hour rule, where water cannot be impounded for extended durations) and may cause usage conflicts. If a project affects flood risk management, county zoning and local government requirements come into play.

6.2.2 Design and Implementation Challenges

Challenges related to Design and Implementation project processes were rated similarly to Purposes and Authorities, that is, rated on median as 6.5 or “somewhat challenging” (See Appendix 2). Major terms related to design challenges was the need for technical expertise, adaptive management, and community participation (Figure 5). Contracting mechanisms for NNBF are difficult to navigate given extended performance timelines and lack of technical expertise. Associated risks and uncertainty from these more natural interventions are difficult to comprehend.

Design for NNBF is inherently cross-disciplinary, requiring collaboration. NNBF projects require systems thinking, so more coordination and education is required to ensure success and buy-in from the many stakeholders. The definition of what constitutes NNBF varies widely. The concept of what is the “right” treatment varies among practitioners and can become seemingly territorial based on a given practitioner’s expertise. Since there will likely be several disciplines or agencies involved, some land management strategies or agency policies may not be aligned with NNBF. Even while there are case studies where similar issues have been mitigated with green infrastructure, some practitioners may continue to rely on traditional or grey infrastructure.



Figure 5. Word cloud from the Design and Implementation Poll (n=12).

Among the workshop discussion, there were varying opinions as to the roles of engineers in NNBF implementation. From one perspective, engineers are needed to design and reduce adverse outcomes related to erosion, water conveyance, and material integrity. On the other hand, there was discussion that NNBF doesn't require engineering-level design and the need for stamped drawings presents unnecessary challenges. While USACE engineers have implemented impermanent solutions on the coast (e.g., coastal sand berm/dune migrations), the potential impermanence of forest or mountain-related structures for flood risk management seems to be a more challenging to practice.

More data is needed to support NNBF implementation. There is uncertainty about the efficacy of NNBF, including lack of documentation of benefits and costs for construction. There is pervasive lack of trust in NNBF approaches being suitable, from both from practitioners that participate in the design process and from the public. There is a lack of design and engineering guidance to support studies and modeling processes. Also,

current contracting structures select the lowest bidder, which may lead to inexperienced contractors and less effective installations, reinforcing perceptions that NNBF are inadequate.

6.2.3 Monitoring and Measures Challenges

Monitoring challenges were rated the highest among the project processes, with a median rating of “8” or “Difficult” and all ratings falling in the 7-10 range (See Appendix 2). “Funding” came up as a challenge among 65% of the respondents (Figure 6).



Figure 6. Word cloud from the Monitoring Poll (n=17).

When implementing NNBF, often there are monitoring/adaptive management needs because the outcomes for these designs are less certain. Given the vision of nature-based approaches, monitoring scopes include not only the structures, but the system. There is a lot of uncertainty in natural environments which makes it difficult to untangle project actions from system processes.

Funding was widely identified as an issue, affecting the level of training for field monitors, recruiting appropriate expertise,

acquiring appropriate equipment, limiting the number of samples, and ultimately monitoring being neglected in project spending plans. Lack of monitoring adversely affects the identification of “lessons learned” to be applied at future projects or as adaptive management. It is also difficult to quantify project success without monitoring.

There was also discussion about the timing of monitoring. Pre-project monitoring to establish a baseline is often neglected. Without a period of record, long-term trends are difficult to identify. After projects, monitoring may not be timed to match life cycle histories such as seed germination. In some systems, it may be difficult to assess hydrologic history. It may be difficult to identify flood events occurring in between monitoring events, particularly to identify what runoff event contributes to structural failure of features.

There was expressed interest in standardizing monitoring protocols so that information about NNBf design can be transferred. However, there are a lot of different projects and performance metrics which makes standardizing monitoring data collection difficult. Ideally, performance monitoring would meet ecological monitoring standards – e.g., geomorphological measures; but there’s uncertainty as what indicates “success”.

Standard monitoring methods may miss important variables, and there may be different perspectives on which variables are most useful and should be recommended for monitoring long-term success. Monitoring objectives are linked to the project purpose and permitting requirements, which vary by agency missions. The data collected is also limited to the skill of the surveyor and the organization’s capacity to monitor. There are challenges to standardizing monitoring because of the potential variance of sites and features. There were mixed opinions about rapid assessments. Some practitioners find them to be less accurate, and others indicating that this is the best means to get big-picture information.

Once data is collected, information transfer and availability among different agencies and organizations are limited. This

may lead to duplicating efforts, and lack of awareness regarding where data may be accessed.

6.2.4 Social and Cultural Challenges

All engineering endeavors are attempts to solve human problems, and yet engineers have a reputation for being more focused on processes than people. The social factor tends to be unpredictable. Uncertainties can result in failure, and failures can result in injury or death to people. As a result, engineers tend to be conservative in their approach to solving problems. Conversely, engineers have to solve problems in a rapidly changing world in which technological development and innovation has impacted earth's ecology.

In the realm of civil works of all types, engineers are increasingly tasked with complex problems in which human activity is inextricably linked with nature. A holist approach is required to identifying, understanding, and solving problems associated with these complex systems. As early as 2012, academics and practitioners began to identify this relationship as the nexus between Social, Ecological, and Technological (infrastructure) Systems (SETS) or Social-Ecological-Infrastructural Systems (SEIS) (Ramaswami 2012) but this paradigm has not been widely embraced by the engineering profession. Throughout the workshop, participants repeatedly noted that cultural change was need across the engineering profession and within agencies like USACE for NNBF to be more widely accepted as legitimate solutions and more frequently incorporated into flood-risk management and water security strategies and projects.

An additional complicating factor for USACE and other government entities in embracing NNBF is the influence of organizational culture that prizes certainty and eschews approaches deemed insufficiently proven. As a government entity spending federal taxpayer dollars, USACE's organizational culture tends to be conservative when it comes to successfully executing lasting, effective projects. Additionally, current federal policies and priorities may diverge from those of states, regions, and communities, further inhibiting adopting of

NNBF when and where appropriate. It is also likely that USACE processes and procedures in evaluating and developing solutions to problems in the realm of flood risk management and water security inadvertently privilege conventional grey infrastructure over reasonable alternatives. All of these human factors produce headwinds to the adoption of NNBF.

Workshop attendees expressed interest in the availability of tools to aid in decision-making related to employing NNBF. The group recognized that engineers preferred quantitative data because numbers are viewed as more solid and objective. And yet, in the realm where not all elements of valuation under consideration can be expressed numerically, there was curiosity about what types of qualitative data could be both meaningful and useful when analyzing the costs and benefits of alternatives. Ultimately, the consensus within the group was that case studies, policy analysis, and effective monitoring and documentation of the effectiveness of projects involving NNBF would provide a foundation upon which wider adoption of these methods might be built.

7 Opportunities and Unique Benefits

Throughout the workshop, benefits and opportunities presented by NNBF implementation were discussed. These benefits are collated here.

Nature-based solutions that mimic natural processes should have better long-term outcomes. By working with nature and natural processes, there is greater opportunity to enhance other ecosystem function, potentially lower adverse impacts and reduce destructive flood flows. In urban and semi-urban environments, NNBF has opportunities to provide shade, mitigation for air and stormwater quality issues, traffic calming, beautification/aesthetics, mitigation for urban heat island impacts, improved health, and provide wildlife habitat.

NNBF has potential to reduce flooding issues by several means. If space is available there is a potential to restore floodplain inundation processes. Over time NNBF may improve soil structure and therefore increase water retention by encouraging termites and other invertebrates, beneficial fungi, and other soil organisms. It can provide the opportunity for water to slow down to infiltrate into the soil, sustaining plants, or increasing wetland areas. It can bring more shade along the rivers to improve water quality and reduce evaporation.

When compared to traditional hardened engineering approaches, NNBF provide greater support for many cultural values such as hunting and fishing, recreation, flood and fire hazard mitigation, habitat, and water quality. Hardened engineering approaches will almost certainly fail over time while natural solutions offer potential for adaptation through natural processes. NNBF construction practices introduces fewer chemicals and legacy materials such as concrete into the ecosystem.

NNBF has opportunities to reduce costs when compared to hardened engineering approaches. Onsite materials can be used in most cases. This allows work to occur in more remote areas where access is restricted, especially considering heavy

machinery. Less ground disturbance for access routes reduces impact footprints which in turn may present efficiencies with cultural resources and other types of clearances. NNBF offers flexibility by being easier to repair and maintain. There are opportunities to consider NNBF when upgrading existing infrastructure to both improve effectiveness and mitigate adverse impacts.

However, the hardened engineering approaches are still a tool that is needed and may be able to compliment NNBF in certain areas. Projects don't necessarily have to be one or the other, but components of any given project may require both approaches. NNBF can be used to protect long term functional capacity and ownership – therefore hybrid systems may be beneficial.

NNBF can bring more trust between the government and community members. NNBF can highlight local and indigenous science. The hand-building aspect of many NNBF allows for communities and youth to be involved. This presents an opportunity to develop skills and expertise in local communities and enhance connection to and stewardship of the landscape. Additionally, the scope of NNBF approaches require partner networking. These discussions may shine light on what other people are doing in the watershed, elucidating collaborative opportunities and more comprehensive problem statements.

8 Recommendations

Discussion at the workshop pointed to many needs to advance NNBF. There is need for more design resources and guidance, needs for more information about design criteria and monitoring requirements, and needs for better understanding of regulatory processes on the federal and state levels. Specifically, guidance on how to develop clear NNBF design objectives, how to link monitoring to assess design achievements, and recommending monitoring techniques including what to monitor and how often.

Design guidance may include standard drawings, technical specifications, analysis workflows, and design workflows. Best management practices and lessons learned can be incorporated to further improve design guidance. Specifications do not need to be set in stone and can evolve as more projects are completed. Practitioners should experiment to make natural and hybrid techniques more effective. Methods to verify that natural features are as resilient as hardened features should be developed. This may require willingness to try new things and utilizing risk-informed decision making. An additional strategy may be project succession planning so that ongoing maintenance is minimized.

Leverage points for NNBF in the design process may be in benefits and efficiencies creation in projects. The paradigm should be to align engineering with nature instead of trying to control nature. Environmental and cultural concerns should not be seen as a barrier to address at the end of planning but incorporated throughout the project process. Further, NNBF may allow for pro-active measures, such as implementing projects to restore system resilience prior to a potential wildfire or flood event.

Given variance of site contexts, monitoring plans should allow for flexibility among projects, namely how and what to monitor. Figure 7 demonstrates a tiered approach to help inform monitoring plan development to move from “Ecosystem Components” to “Monitoring”.

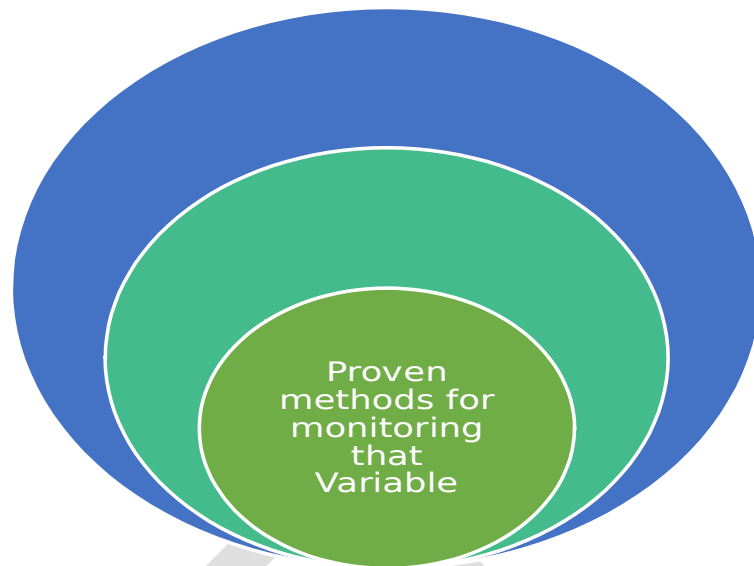


Figure 7. A suggested framework for monitoring guidance.

It is also necessary to consider how monitoring methods are evolving, for example, the use of drones increases the coverage of visual monitoring.

Research may be needed to link NNBF monitoring criteria to project performance, for example, how do materials used break down and how does this affect project performance? Another research need is the scalability of NNBF implementation and measuring landscape-scale benefits.

Collating case studies for the arid southwest is needed and can take the form of maps of NNBF project areas, and interviews with community members on how NNBF projects have improved outcomes. Cost data are needed to be able to compare with conventional hardened engineering approaches. Performance data about these NNBF, as well as relevant design and specification information, can increase the confidence of applying NNBF. The public needs to be made aware of these successes for more buy-in to support incorporating these features more frequently.

It was acknowledged that regulations can steer design. Local codes and elected officials both have influence, such as by promoting resilient design requirements. Incentive programs

are motivators. Additional funding is needed, but also importantly: The funding needs to be matched with the right agency or individuals for the job.

Criteria for success are tied to regulatory requirements, but to go further: funding is needed to disseminate information and developing mechanisms such as public databases are needed to host the information. Collating important papers would be a feature of this technology transfer. NNBF requires different operating techniques than traditional engineering and therefore may require training. These techniques should be taught in engineering programs at Universities.

Mitigation banks were raised as an option to enable NNBF programs. In-lieu fees can be a mechanism to support compensatory mitigation. In constructing NNBF, mitigate and avoid adverse impacts to processes, and assess how NNBF is restoring these processes.

Community engagement is important to convey newer techniques to normalize them. Continuing to connect as a community such as the riverscape restoration network, beaver coalition and workshops such as this one is important to continue the momentum of NNBF implementation. The real need is staying power for individuals that run these projects. When personnel turnover is high, project momentum gets stalled. It would be pragmatic to be creative about how to keep multiyear multi entry projects moving forward as changeover occurs.

9 Summary

Practitioners from 18 organizations participated in an engaging 2-day workshop on NNBF for the arid southwest at the USACE Albuquerque District in May 2025. The workshop was organized around three project processes: Purposes and Authorities, Design and Implementation, and Monitoring and Measures. Of these, monitoring and measures was identified as most challenging. Monitoring would be instrumental in assessing current NNBF implementations and improving confidence in these techniques.

Over 50 different types of NNBF structures for arid environments were identified on a spectrum from green to hybrid approaches, several existing design and monitoring resources were identified by workshop attendees, and a draft framework for NNBF implementation was assessed. This report covers the state of the practice, challenges, opportunities and recommendations for advancing the utilization of NNBF to reduce flood risk and restore ecosystem function. The challenges identify the need for guidance and increased communication of successes and lessons learned. Opportunities range from increased project function, better societal benefits, and methods to reduce perceived and actual risk in using NNBF technologies.

Parking lot:

- Hot soils, Saline, sodic, highly dispersive soils
- What are the assets – scenic beauty, species, renewable resources, fertile soils,
- How can we build resiliency? (Community? -)
- How can we build resiliency? (Ecosystem - with eye towards 2nd order effects => physical safety of communities by protecting communities from likely impacts of extreme weather
- Habitat creation and developing resilience are also considerations
- The need for collaboration/partnerships was a recurring talking point during the Theme 1 discussions during the breakouts.

- Human assets – with people, community
- Cultural assets – heritage, spiritual connection, traditions, myths/legends – share the story
- Paper by coastal engineers to incorporate EWN techniques
- RAWR (Right Answer, Wrong Reason?)
- what is the carbon offset of this project,
- Carbon sequestration
- materials/contracting: agreement v. contracts, BAER restrictions – [limited where work can be done; upstream and downstream areas need to be addressed as well], USFS heavy equipment contractor w/expansion capability to incorporate NNBF [there is a standing USFS contract that allows the contractor to shift equipment around according to where it's needed for response post-fire, flooding/debris flow or during the fire. Use of this in advance, may allow a lot of work to be done by the time the BAER team gets onsite.], Different operating techniques: younger crews
- Also having a greenhouse nearby to use plants that are needed.
- Green Infrastructure, Revegetation Standards., invasive species removal, multiple entreats,
- While there are many issues with expecting people to do work for free, partnerships with universities may be a key providing labor for monitoring while not being burdensome to individuals looking for a job.
- Youth Corps or BLM / State Partnership have been successful elsewhere
- agency already have, usually timing on results is compiled in a timely manner, (uncertainty on what requirements are necessary)
- Using indicators of success (Karen Menetrey has these)
- Ecosystem metrics
- expectations on what to collect based on goals, unintentional consequences; one rock dam that beavers added to.
- Material issues arise with the destruction of markers and benchmarks.

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Workshop attendees, with special thanks to our speakers **in bold**:

<i>Organization</i>	Attendees
<i>American Rivers</i>	Emily Wolf
<i>Amigos Bravos</i>	Steven Fry, Talavi Cook
<i>Audubon</i>	Tucker Davidson
<i>Bernalillo County</i>	Kali Bronson , Bobby Mullin
<i>Bohannon Huston Inc.</i>	Stuart Trabant
<i>Hermits Peak Watersheds</i>	Lea Knutson
<i>International Boundary and Water commission</i>	Rita Crites
<i>National Forest Foundation</i>	Martha Egnal, Katie Sickmann
<i>NM Department of Game and Fish</i>	Jasmine Johnson, Jack Marchetti, Carrie Parris, Corey Webster
<i>NM Energy Minerals and Natural Resources Department</i>	Joey Fleming, Allison Moore, Emily Stout
<i>NM Environmental Department</i>	Ashlie Carabajal, Jocelyn Harimon, Alan Klatt , Maryann McGraw, Susan Styer
<i>Rio Grande Return</i>	Karen Menetrey , Cameron Weber
<i>Santa Ana Pueblo</i>	Nathan Schroeder
<i>Santa Clara Pueblo</i>	Garrett Altman

<i>Organization</i>	<i>Attendees</i>
<i>South Sandoval County Arroyo Flood Control Authority</i>	David Gatterman
<i>The Nature Conservancy</i>	Martha Schumann Cooper
<i>Theodore Roosevelt Conservation Partnership</i>	Christian Fauser
<i>Unaffiliated</i>	Pamela Betts, Joneen Cockman , Steve Vrooman
<i>US Bureau of Reclamation</i>	Jacoba Dorely, Logan Gonzales, Cameron Herrington, Shamarie Nez
<i>US Department of Agriculture</i>	Micah Kiesow

Workshop proceedings, including the presentations, can be found here:

<https://ewn.erdcdren.mil/engagements/event/ewn-natural-and-nature-based-features-playbook-for-the-arid-southwest/>

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Appendix A: Workshop Agenda

Day 1

Time	Action	Speaker
8:00 – 8:30	Arrive & check in (Main Conference Room)	
8:30 – 8:45	Welcome/Quick Introductions	Aubrey Harris (ERDC-EL)
8:45-9:00	USACE Albuquerque District Perspectives and Needs	Mark Doles (USACE-SPD)
9:00-9:15	Engineering with Nature (EWN) – NNB Implementation Resources and Playbooks	Aubrey Harris subbing for Burton Suedel (ERDC-EL)
9:15-9:45	Ice Breaker Activity: Reinforcement of the (3) Themes: Purposes and Authorities; Design and Implementation; and Monitoring and Measure. Case Studies.	
9:45-10:00	Break	
Theme 1: Purposes and Authorities		
10:00 – 10:15	-What does Social Science have to do with Ecological Engineering?	Judith Vendrzyk (ERDC-CREL)
10:15-10:30	Tijeras Creek Watershed Restoration Project	Stuart Trabant (BHI)
10:30-10:45	How NNB can support NMED Programs and How NMED Programs can support NNB	Alan Klatt (NMED)
10:45-11:00	Low-Tech Process-Based Restoration on Headwater streams in New Mexico	Karen Menetrey (Rio Grande Return)
11:00-	Workshop Activity 2: Questions, Response to	

Time	Action	Speaker
11:30	Purpose and Authorities Theme	
11:30-1:00	Lunch on your own	
Theme 2: Design and Implementation		
1:00 – 1:20	Stream Applications of NNBF in the Arid SW	Chris Haring (ERDC-CHL)
1:20-1:35	Integrating NNBF’s in Roadway Crossings: Tribal case study from a fire and flood impacted watershed	Garrett Altmann (Santa Clara)
1:35-1:50	Mimicking Beavers	Jonathan Aubuchon (USACE-SPA)
1:50-2:05	National Forest Foundation Watershed Program	Katie Sickmann, Martha Egnal (National Forest Foundation)
2:05-2:30	Workshop Activity 3: Questions, Response to Design and Implementation Theme	
2:30-2:45	Break	
Theme 3: Monitoring and Measures		
2:45-3:00	Role of Landscape Architecture in the Playbook, Reporting Framework	Steven Bailey (ERDC-CHL)
3:00-3:15	From Performance to Persistence: Honoring Historic Acequia Systems with NNBF	Rodrigo Seden (USACE-SPA)
3:15-3:30	Bernalillo County Green Stormwater Infrastructure & Low Impact Development Standards.	Kali Bronson (Bernalillo County)
3:30-3:45	Sediment Monitoring: Telling the Whole Story	Jony Cockman
3:45-4:15	Workshop Activity 4: Questions, Response to Measuring and Monitoring Theme	
4:15 – 4:45	Summarize and Adjourn Day 1	
5:00-6:30	Optional no host social opportunity: Sawmill Market Courtyard	

Day 2

Time	Action
8:00 – 8:30	Arrive (Main Conference Room)
8:30 – 9:00	Plenary: Introduction of Breakout Group Process
9:00 – 9:45	-Breakout Session #1 - Understanding what exists to support EWN/NNBF and associated challenges
9:45-10:00	Break
10:00 – 10:45	-Breakout Session #2 - Informing the Framework to address challenges
10:45 – 11:00	Break
11:00-11:45	Plenary: Session Report Out & Discussion of Results (15 mins per theme)
11:45 – 12:00	-Closing Thoughts & Next Steps
12:00	Workshop Adjourns (Lunch on your Own)

Appendix B: Raw/Uncoded Poll Results

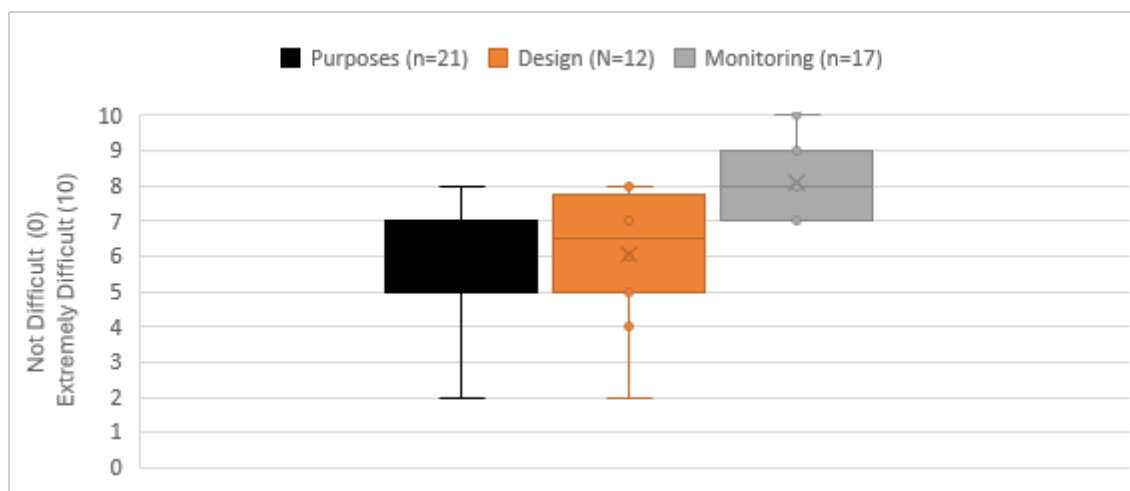


Figure 8. Each poll, taken at the Q&A session after each presentation module, asked the same question: “How significant are the challenges associated with this theme”. Figure shows the distribution of results from 0 = Not Difficult to 10 = Extremely Difficult.

Table 2. Each poll, taken at the Q&A session after each presentation module, asked the same question, “In a word, name these challenges [associated with this theme].”

Poll 1: Purposes and Authorities

Knowing what authorities are involved in which areas

Permitting/regulatory

Funding

Maintenance

Federal administration restrictions on environmental themes

Permitting, Compliance, Funding, Engagement

Fluctuating

Permitting hurdles and cost and capacity challenges for small organizations associated with going through the permitting process.

Bureaucracy

Inflexible regulations, drought, public acceptance of “messy” natural solutions, multiple uses (recreation, grazing, etc.), need for stamped engineering designs that don’t allow for low-tech solutions

Politics, contracting challenges, funding,

Can be overcome. Culture change. Politics. Time it takes to

Poll 1: Purposes and Authorities

collaborate & learn to think holistically.

Understanding regulations

Interpretation

Interpretation

Mandates, lack of consistency of regulations and BMPs over time, popular approaches are implemented incorrectly and this degrades legitimacy, monitoring funding for effectiveness

Political

Risk avoidance, urban vs rural solutions, ephemeral vs perennial

Guidance

Making funding go further

Regulatory

Poll 2: Design and Implementation

Tolerance for complexity in natural systems

Uncertainty

Knowledge

Funding, Monitoring support, permits, clearances, partner support

Risk to Infrastructure/ Liability

Acceptance, incorporation, coexistence

Consistency of techniques, professionals who know how to implement

Long term

Contractor proficiency. Etc.

Some project proponents are not able to contract with small restoration firms with the most experience with these practices; rules that recent the design firm and the implementation firm being the same entity; short funding windows; flooding and other weather that require adaptation and flexibility

Familiarity with techniques

Paradigm shift

Poll 3: Monitoring and Measures

Funding for monitoring is extremely difficult to find

Funding for monitoring

Funding

Community support

Short monitoring period

Poll 3: Monitoring and Measures

Money for collecting post construction data, staff time, how to collect data so dataset is robust

Performance

Time and funding

Funding

No funding mechanisms, lack of standardized approaches to monitoring

Scale, drought, intense [precipitation]

Funding and timeline of projects

Time required.

Diverse

Lack of funding for monitoring.

Perceived value of the data collected

Lack of funding

Funding

Appendix C: Draft Framework

USACE supplied a draft framework of analytical approaches for NNBF for feedback in the final breakout session. The following are a potential list of elements considered during the design, implementation, and monitoring of Engineering with Nature projects that use natural and nature-based features (NNBF)

Theme 1: Project purposes

- **Flood risk management** (flood water storage, peak flow reduction)
- **Sedimentation management** (erosion control – bank and channel degradation, sediment storage, channel aggradation, debris flow management)
- **Infrastructure protection** (protection of levees, roads, railroads, communities)
- **Ecosystem rehabilitation** (restoration of floodplain dynamics, groundwater recharge, aquatic health, restoration of habitat destruction/creation processes)

Theme 2: Design Requirements

Hydrology

- Choice of flow used for design – considers flow frequency, duration, magnitude.
- May be explicit (e.g., 2-yr rainfall runoff storm) or implicit (bank full discharge)
- May consider gaged data or employ a watershed analysis.
- Post-wildfire scenarios need special consideration as this causes a large change in rainfall-runoff from existing conditions.

Hydraulic analysis

- Consideration of forces impacting feature, typically a velocity or shear stress
- Forces may be determined through a physical scale model, a numerical hydraulic model, or some other method (developed nomographs, empirically developed equations for shear stress, experience of practitioners familiar with the fluvial system, etc.)
- Permissible material forces are typically determined from tabulation of existing field/flume studies that evaluated performance of certain material types. This may also be done

based on experience of practitioners familiar with the fluvial system.

Sediment Transport

- Consideration is given to how sediment transport may impact the fluvial system with the features in place.
- This may be a qualitative assessment using fluvial relationships (Lane's balance) or experience of practitioners familiar with the fluvial system or a more quantitative study involving a sediment transport numerical model.
- Long-term erosion and/or local scour may also be considered in these studies
- Erosion countermeasure designs may also be evaluated to assess if the chosen feature is adequately sized for a given system.
- Post-wildfire scenarios need special consideration as this causes a large change in rainfall-runoff from existing conditions.

Fluvial geomorphology

- Evaluation of the ways a fluvial system can adjust its form.
- The evaluation looks at changes in a system that have occurred over time to predict ways the fluvial system form may adjust in the future.
- Depending on the project impact these may be qualitative changes based on experience evaluating similar feature responses over time or using fluvial system relationships, such as Lane's balance. These may also be more quantitative and require field measurements to ascertain the current conditions and compare to a reference reach or repeat measurements in time to understand the fluvial system being impacted.

Theme 3: Monitoring requirements

- Repeat visual inspections to assess the performance of the feature.
- Monitoring would evaluate history of hydrology (frequency, duration, magnitude) of floods the feature has been subject to since installation, what erosion, if any, has occurred, if the feature is working as intended, etc.
- Monitoring would typically include repeat photographs of the site over time.

- Monitoring may include measurements of fluvial morphology metrics (width, depth, slope, sinuosity, planform, etc.) to evaluate how the fluvial system is adjusting over time.
- Monitoring may include biological changes because of the impacts to the hydrology, hydraulics, sediment transport, and fluvial geomorphology. These may include changes to vegetation, macroinvertebrates, birds, mammals, etc. Note that changes to larger animals may require substantially more time to effectively draw a conclusion because of the dynamism associated with those populations.
- Monitoring may also include water quality metrics to ascertain effectiveness.
- Monitoring should be tied to original project goals and ideally would be tied to an adaptive management schema that can implement adjustments to feature locations to improve the overall project function. This likely requires monitoring and adaptive management timeframes on the order of the channel forming floods.

Appendix D: Workshop Worksheet

The following quadrant was supplied as a worksheet to gather written information of the four items.

List key design resources for NNBF in arid regions (<i>e.g., EWN NNBF Design Book</i>)	Important example projects and case studies (<i>e.g., beaver dam analogs</i>)
Key challenges for executing NNBF in arid regions (<i>e.g., revegetation in a drier climate</i>)	Take-home messages from Day 1 of the workshop

Appendix E: Post Workshop Survey Results

What are challenges are you facing in the adoption of NNBF in arid environments?

Recognition of ephemeral streams as riparian resources.
Excluding livestock year-round from habitat restoration projects for at least several years.
Recognition of irrigation as a needier resource to initiate grassland restoration.

Culture & people staying in silos. Lack of clear cost/benefit analysis & shareable case studies,

The definition of what constitutes NNBF as this varies widely. The concept of what is the "right" treatment to do among different practitioners and I see groups forming that defend one type of treatment concept and try to put down others. Also, the need to think bigger, watershed scale planning and projects that look to larger areas will move us towards efficiencies through clearances and permitting. There is also a need to incorporate permits that have multi-year project timelines (extend beyond 5 years), how can we make this more efficient.

Funding.

Demonstrated examples of performance

A challenge for adopting NNBF in arid environments is getting people to consider NNBF as a viable design option early on in project development phase.

Because we do work on other agency lands, we might run into folks whose land management strategies may not be align with NNBF. Also, there might be some projects will solely need to rely on Grey Infrastructure. Before doing grey infrastructure, consider how places around the country or world have mitigated big projects with green infrastructure.

Design guidance; documented post-construction success; agency/public perception

Need arid-adapted NNBF designs; there are not classes in colleges that incorporate NNBF for engineering schools, so graduating engineering students are not familiar with these practices; designing NNBF with maintenance in mind; not enough NNBF installations and data showing performance so that engineers are comfortable designing with and using

What are challenges are you facing in the adoption of NNBF in arid environments?

these features/BMPs; need to change public perception of what landscapes in arid environments look like.

permitting, adequate competent contractors who can design/implement at a reasonable cost, funds/support for monitoring

Lack of completed examples, proficient designers/contractors, regulatory support

What factors may enhance the adoption of NNBF in arid environments?

Design still needs the involvement of engineers to measure hydraulic forces, angle of repose, etc.

Developing a community of practice around this. Agencies pushing it (incentives?) & supportive policies (local, state, federal)

Continuing to put these treatments on the ground and a commitment to follow-up monitoring. Comfort levels will rise when more of these types of treatments are known. Monitoring will help with adaptive management. There is also a need to tell the story of treatment effectiveness over the long term. A continued understanding that some of these treatment actions depend on the system doing the work which means high flow events that “work” the system with the right “ingredients” (wood, beaver mimicry, vegetation, etc.) are key as opposed to a just a set number of years until project success is reached. Additional workshops in the field with multiple stakeholders. The real need is staying power for individuals that run these projects. As turnover is high in my agency and as people move, project momentum gets stalled. We need to be creative about how to keep these multiyear multi entry projects moving forward as changeover occurs.

Scale and effectiveness. Both at smaller scale will be more accepted quicker.

Verification that designs can handle same loads and forces as conventional designs

To enhance the adoption of NNBF in arid environments, regulatory agencies could include a Box in the PCN that project proponents must fill-out and explain why NNBF would

What factors may enhance the adoption of NNBF in arid environments?

not work for their project if they're project is "grey" only.

Conservation Research from local colleges/universities, Tribal consultation, Community consultation

Prepare design guidance; documentation of post-construction success; seek out agency feedback

Performance data for NNBF; standard designs for NNBF; public buy-in for aesthetics of native landscapes in arid environments

More institutional support/understanding (the Arid SW Playbook would be an amazing resource)

Cost effectiveness and being nature positive. Perhaps NNBF's can be considered compensation, or even a requirement for projects that result in habitat alteration/loss.

What has worked for your organization to encourage consideration or implementation of NNBF?

Working with cooperative partners.

Identifying good partners to help implement the work, tell the story and stay on top of the monitoring. The completion of a conditions based Environmental Analysis has helped with efficiency for work being completed on the ground. Just starting these types of projects and moving forward on pilot projects has been advantageous. Knowing these are not one and done types of projects and fulfilling commitments to multiyear efforts.

It's kind of what we do...

Planners and engineers

To encourage the implementation of NNBF, the Surface Water Quality Bureau has included a CWA Section 401 specific denial for bank stabilization projects (NPW 13) that propose to line channels with concrete.

Showing the work to the community and partners helps implementing NNBF

Client desires/requests

Getting grant funding for projects that include NNBF so that the installation of NNBF is essentially required. Developing standards and standard drawings for GSI

Corporate funding from Walton that is targeted at LTPBR

What has worked for your organization to encourage consideration or implementation of NNBf?

(Low Tech Process Based Restoration)

Aligning with cultural priorities of minimizing the amount of foreign materials introduced into natural systems.

What types of NNBf have worked well in your organization's projects?

One rock structures across the landscape to increase infiltration.

Wide accessible floodplains.

Projects that focus activities on erosion control, head cut and grade stabilization, large wood and boulder projects, beaver habitat restoration, riparian vegetation planting (with protection, (fencing)) and range management improvements.

Bankline stabilization, channel creation.

PALS

Beaver Dam Analogs, Willow Habitat Restoration, One Rock Dams, etc.

GSI; LID; bio-engineered channel and slope stabilization

Green stormwater infrastructure (GSI) such as rainwater harvesting basins, bioswales, curb cuts, etc.; root wads; reconnecting waterways to the floodplain; rock riffles; soil riprap with coir mat

LTPBR- beaver dam analogues, one rock dams, cross vanes, willow planting, plug and pond, keyline plowing/imprinting/seeding (KIS) on large flat areas, etc.

Culvert upgrades, bank stabilization, sediment management.

What are the primary factors you consider when designing and constructing NNBf?

Hydraulic measurements, excluding livestock long enough to allow vegetation establishment or recovery.

Finding engineers to design [NNBF].

Areas with past projects and investments. Partner and cooperator interest. Municipal water supply. State action plans. High risk areas for fire. Species habitats specifically for T&E species. Potential multiple use conflicts (water rights, grazing, recreation and wildlife habitat). How these projects

What are the primary factors you consider when designing and constructing NNBF?

connect to upland treatments - Identifying project areas where upland vegetation treatments (timber and fuels) are occurring to treat the watershed holistically. Some of these project activities can also be beneficial to increase resiliency in the system when additional inputs of water, sediment and energy are expected from upland vegetation treatments. Moving towards focused landscape scale planning as opposed to random acts of restoration. Scale of the projects, gradient of the project areas and most importantly stakeholders that may be affected by project activities or manage lands in, around or downstream of these areas.

Does it fit the project goals.

What is my purpose? What flow does this have to handle?
What is my end goal?

Ex Situ vs In Situ approach, using local materials, who and how is the project benefiting, what is the carbon offset of this project, what ecological services are you helping, does this benefit humans and wildlife to coexist, is it ecologically sustainable, are the Indigenous people and other land-based communities within the watershed of the project being talked to about this project, is Traditional Ecological Knowledge being considered,

Hydrology, hydraulic conditions, geotechnical considerations; cost of implementation; potential for revegetation

location in watershed, area drained, soil type and steepness of grade, land use and related constraints, accessibility for laborers/material/equipment

What natural process are occurring and how can NNBF's be integrated to work with them, versus conquer them. Habitat creation and developing resilience are also considerations.

What information would be needed to inform NNBF implementation (such as in spec-sheets or frameworks), particularly in arid environments?

Recognized monitoring protocol.

Not my area of expertise

Continuing to advance ways to connect as a community such as the riverscape restoration network, beaver coalition and

What information would be needed to inform NNBF implementation (such as in spec-sheets or frameworks), particularly in arid environments?

workshops such as this one. Dynamic spec sheets that are not set in stone and can evolve as more projects are completed. Informed monitoring protocols or as one of the attendees mentioned a “monitoring menu” that is accepted.

Case studies. Not that dissimilar that what we discussed when we're all sitting in a room together talking about projects.

Test cases

pamphlets, story map of NNBF project areas, interviews and stories from community members on how it's helped the community and watershed

Standard drawings; technical specifications; analysis workflows; design workflows

NNBF performance data, standard designs for NNBFs; specs for when and how to use NNBF

Completed examples and best management practices.

When compared to traditional hardened engineering approaches, what opportunities does NNBF provide, particularly in arid environments.

Encourage termites and other soil organisms.

Work better, last longer. Offer flexibility (easier to repair/maintain)

Cost effectiveness - onsite materials in most cases can be used. Increases potential for work to occur in more remote areas where access is restricted, especially considering heavy machinery) headwater systems. Less ground disturbance for access routes. More efficiency with clearances specifically from cultural resources when less reliance on heavy equipment is required for project implementation. Allows for communities and youth to be involved. However, the hardened engineering approaches are still a tool that is needed and may be able to compliment NNBF in certain areas. Projects don't necessarily have to be one or the other, but components of any given project may require both approaches.

A general alignment with nm values.

If space is available there is a potential to restore processes

When compared to traditional hardened engineering approaches, what opportunities does NNBF provide, particularly in arid environments.

like floodplain inundation over time

When compared to traditional hardened engineering approaches, NNBF provides greater support for many cultural values (such as hunting and fishing), recreation, hazard mitigation (flood and fire mitigation), habitat, and water quality.

NNBF provides less chemicals into the ecosystem as concrete is not eco-friendly, it can provide the opportunity for water to slow down to make more wetlands, it can bring more shade along the rivers, it can bring more trust between the government and grassroots community members instead of animosity, it can provide a space for BIPOC science and research to be highlighted and used for NNBF projects

Hardened engineering approaches will almost certainly fail over time while natural solutions offer potential for adaptation through natural processes.

Nature-based solutions that mimic natural processes should have better long-term outcomes; in urban and semi-urban environments they provide shade, cooling, mitigation for air quality issues, mitigation for stormwater quality; traffic calming, beautification/aesthetics, mitigation for urban heat island impacts; provide wildlife habitat when using native plants

working with nature and natural processes, greater opportunity to enhance other ecosystem function, potentially lower impact and lower embodied energy, opportunity to develop skills and expertise in local communities and enhance connection to and stewardship of landscape/environment

Cost-effectiveness, habitat creation, resilience

Please feel free to provide any positive or negative feedback about the workshop.

Great job. Good to meet in person. I don't think you would have had the same impact with a remote venue.

So great. Thank you.

I was unable to make the second day, but I feel like that day may have been the most useful. Smaller group breakouts with

Please feel free to provide any positive or negative feedback about the workshop.

discussion are key to successful outcomes with these types of workshops. I will also follow-up with an email to share design documents, literature, research and monitoring. Great work bringing this group together and starting this effort for the southwest.

It was a good workshop. Hoping you got what you needed.

Really well organized and put together, thank you! It would be interesting to have broader stakeholder involvement and to hear from those who provide critical hard engineering services, to better understand what the limiting factors are from an engineer's perspective for implementing NNBFs, to see if more hybrid solutions might be developed.

This was a great workshop. I learned so much and I hope I was able to provide some great feedback as well.

Fantastic workshop! As an engineer I am excited to see NNBS are getting some attention and momentum.

I loved the workshop! I hope to see more of these kinds of workshops in the future and am looking forward to the playbook that comes out of these efforts!

It was a truly awesome experience- the content, the networking, the conversations- really inspiring, informative and generative. Very interested in exploring opportunities to partner w/long term projects happening in the lower Colorado River Basin across the National Forests to help develop the playbook.

Fantastic gathering of diverse folks in the region. It's great to finally have the District involved and pursuing this type of work. Thank you!!!

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